CHEMICAL COMPOSITION OF THE TISSUES OF THE SARRACENIACEÆ

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Chemical Composition of the Dried Plants

Specimens of each North American species of the *Sarraceniaceæ* were gathered in the native habitat, in the spring or early summer unless otherwise stated. Rhizomes and pitchers of each species were collected at the same time, but were studied separately. Analyses were made of open pitchers of all species, and of closed pitchers of certain species.

The rhizomes were dug, and washed in running water until free from adherent soil. Dead tissues were removed by trimming. The rhizomes were then spread out, and dried in the air.

Closed pitchers were slit to remove the liquor, then spread out and dried in the air. Open pitchers were slit to the base of the cavity; their contents were completely removed by scraping with a blunt instrument, followed by washing in running water. They were then spread out and dried in the air. Each sample contained from 10 to 60 pitchers.

Prior to analysis, each sample was ground in a drug mill until the entire mass passed through a sieve with 20 meshes to the linear inch. The weight of the sample naturally varied with the abundance of the species and, in the case of the pitchers, with their size. The analysis was made according to the methods of the Association of Official Agricultural Chemists.[80] The results of the analyses are presented in Table XI. The water content has been reported as percent of the air-dried tissues, the other constituents as percent of the total solids. Crude fat is a synonym for ether-extract, crude fiber for cellulose. The nitrogen-free extract includes all carbohydrates except cellulose, and all organic acids. The soluble ash is that portion of the total ash which dissolved in boiling water, while the insoluble ash is the portion which was insoluble in that solvent. The alkalinity of the ash was determined by means of tenth normal hydrochloric acid, using methyl orange as an indicator; it has been reported as cc. of normal acid required to neutralize the ash (soluble or insoluble) yielded by 100 grams of total solids.

The following conclusions are based on a study of the results recorded in Table XI.

With two species (*Sarracenia Sledgei* and *S. Drummondii*), closed pitchers and open pitchers were analyzed separately. The open pitchers contained more crude fat, more crude fiber, less crude protein and less total ash than the closed pitchers of the same species.

The pitchers and the rhizomes of each species may be compared with each other. The rhizomes of *Sarracenia purpurea* were gathered at the same time and place as its "early season" pitchers. As a rule, the rhizomes of a given species contained less crude fiber, less crude protein, and more nitrogen-free extractives than the pitchers of the same species.

The insoluble ash was usually less than the soluble ash in the pitchers, while the reverse was true, as a rule, in the rhizomes.

The alkalinity of the insoluble ash was greater than the alkalinity of the soluble ash in the rhizomes of all the species and in the open pitchers of all the Sarracenias.

The nitrogen-free extractives formed more than one-half of the total solids in all but one sample of rhizomes and in all but two samples of pitchers.

The results obtained with the three samples of pitchers of *Sarracenia purpurea* indicate that the chemical composition of the plants depends, in part, on the time of the year at which they are gathered.

Total Solids and Moisture Content of the Fresh Plants

Plants of several southern species of *Sarracenia* were gathered in their native habitat in the spring, and brought to Philadelphia in the live condition. The homeopathic tinctures were then prepared from their pitchers and rhizomes. In the preparation of these tinctures, it was necessary to determine the moisture content of each specimen, by drying a 10 gram sample for 3 hours at a temperature of 100° C. The following results were obtained:—

Pitchers	*Moisture, percent.*	*Total Solids, percent.*
Sarracenia minor	65.10	34.90
Sarracenia flava	80.60	19.40
Sarracenia Drummondii	75.03	24.97
Sarracenia rubra	68.97	31.03
Rhizomes		
Sarracenia minor	58.53	41.47
Sarracenia flava	76.28	23.72
Sarracenia Drummondii	64.58	35.42
Sarracenia rubra	67.50	32.50

TABLE XI.—CHEMICAL COMPOSITION OF THE SARRACENIACEÆ.

	Genus and Species.	Weight of Sample. Grams.	Moisture.	Total Solids.							Alkalinity of Ash.	
				Crude Fat.	Crude Protein.	Crude Fiber.	Ash. Total.	Ash. Soluble.	Ash. Insoluble.	Nitrogen-free Extractives.	Soluble.	Insoluble.
Pitchers, Closed	*Sarracenia Sledgei*	12	5.48	11.61	13.22	17.95	4.15	3.08	1.07	53.07	29.85	28.55
	Sarracenia Drummondii	9.5	6.94	11.58	13.23	17.52	3.77	2.66	1.11	53.90	27.05	22.15
Pitchers, Open	*Darlingtonia californica*	60	5.14	5.04	8.04	21.33	4.36	3.70	0.66	61.23	30.70	16.15
	Sarracenia minor	33	7.56	12.13	7.84	21.96	1.87	1.17	0.70	56.20	13.85	18.60
	Sarracenia Sledgei	24	9.51	13.81	10.50	19.69	2.56	1.71	0.85	53.44	19.00	19.55
	Sarracenia flava	40	7.71	10.38	8.00	30.15	2.13	1.56	0.57	49.34	16.15	20.15
	Sarracenia Drummondii	30	9.09	14.01	10.45	24.78	3.28	2.03	1.25	47.48	19.15	27.85
	Sarracenia rubra	8	5.61	7.80	8.61	23.41	2.03	0.91	1.12	58.15	11.85	13.75
	Sarracenia purpurea early season.	42	7.15	11.72	5.47	20.98	1.91	1.18	0.73	59.92	11.75	19.50
	Sarracenia purpurea end of season.	62	6.44	6.49	7.62	17.26	2.30	1.36	0.94	66.33	6.75	22.35
	Sarracenia purpurea pitchers of preceding year, gathered in spring.	12	9.44	14.35	1.33	17.26	2.37	1.26	1.11	64.69	8.05	30.50
	Sarracenia psittacina	5	5.81	16.87	7.30	18.27	3.12	2.21	0.91	54.44	2.85	18.80
Rhizomes	*Darlingtonia californica*	8	9.83	25.04	7.91	15.57	3.06	1.60	1.46	48.42	14.30	51.00
	Sarracenia minor	35	7.30	21.08	4.72	12.67	2.61	0.28	2.33	58.92	3.45	21.15
	Sarracenia Sledgei	43	7.60	6.63	8.53	15.40	1.75	0.42	1.33	67.69	3.55	21.85
	Sarracenia flava	46	9.46	15.93	8.49	19.65	2.32	0.98	1.34	53.61	8.30	31.90
	Sarracenia Drummondii	57	7.59	10.32	5.86	13.96	3.90	2.30	1.60	65.96	7.15	27.60
	Sarracenia rubra	14	6.20	5.88	5.42	13.54	9.28	0.25	9.03	65.88	3.00	34.00
	Sarracenia purpurea	18	9.02	9.68	3.81	18.10	2.40	0.96	1.44	66.01	4.95	25.95
	Sarracenia psittacina	5	6.28	11.49	6.49	19.71	5.45	0.35	5.10	56.86	4.35	29.75

Moisture is reported as percent of the air-dried tissues, the other constituents as percent of the totals solids, alkalinity of the ash as cc. of normal hydrochloric acid required by the ash in 100 grams of total solids.

In all four species, the pitchers contained more moisture and less total solids than the rhizomes. The tissues of *Sarracenia flava* contained considerably more moisture than those of any of the other three species studied; this was true of both the pitchers and the rhizomes.

Test for Protease in the Rhizome of Sarracenia purpurea

Rhizomes of *Sarracenia purpurea* were gathered at Whitings and Davenport, New Jersey, at the end of May. Separate portions of the cleansed, crushed, freshly gathered rhizomes were extracted for 21 days at room temperature with the following solvents:—

1. Distilled water, containing 0.2 percent trikresol.
2. Hydrochloric acid 0.2 percent solution, containing 0.2 percent trikresol.
3. Sodium carbonate 0.5 percent solution, containing 0.2 percent trikresol.
4. Alcohol 50 percent by volume.

The water, the dilute acid, and the dilute alkali were used in the ratio of 10 cc. of solvent for each gram of crushed rhizome. The 50 percent alcohol was used in the ratio of 4 cc. of solvent for each gram of crushed rhizome this solvent was used since it contained approximately the same percent of alcohol as whisky, the official whisky, *Spiritus Frumenti* of the United States Pharmacopoeia[81] containing not less than 47 percent and not more than 53 percent by volume of ethyl alcohol. Whisky is frequently used as the menstruum for the preparation of household remedies from the Sarracenias.

The extracts were filtered through filter paper. The aqueous extract was a golden yellow; the insoluble residue was black. The 0.2 percent hydrochloric acid yielded a straw yellow extract, and a residue with the color of reddish brown clay. The 0.5 percent sodium carbonate gave a deep brown extract, and a deep purplish black residue. The presence of trikresol, which was used as a bactericide, possibly influenced the colors obtained with these solvents. The alcoholic extract was a reddish brown, the insoluble residue a light brown.

A series of 6 experiments was now made to test for the presence of a protease in the various extracts. In each experiment, 0.2 gram of carmine fibrin was used as the substrate. The period of incubation was 42 days at room temperature. The volume of extract used in each experiment was:—

Experiment 1. Aqueous extract 50 cc.; sufficient sodium carbonate to produce a concentration of 0.5 percent of that salt.

Experiment 2. Aqueous extract 50 cc.; sufficient hydrochloric acid to produce a concentration of 0.2 percent of that acid.

Experiment 3. Extract in 0.5 percent sodium carbonate solution 50 cc.

Experiment 4. Extract in 0.2 percent hydrochloric acid solution 50 cc.

Experiment 5. Alcoholic extract 20 cc.; sufficient sodium carbonate to produce a concentration of 0.5 percent of that salt.

Experiment 6. Alcoholic extract 20 cc.; sufficient hydrochloric acid to produce a concentration of 0.2 percent of that acid.

The trikresol functioned as a bactericide in the first four experiments, while the alcohol acted as a bactericide in the last two experiments.

Absolutely no digestion of the carmine fibrin occurred in any of the experiments. Therefore, a protease was not present in the rhizomes.

BIBLIOGRAPHY

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(Citations 1 to 68, both inclusive, also 87, 89, 94, 95, refer to insectivorous plants. Those from 36 to 63, both inclusive, refer only to the use of the Sarracenias in medicine and have not been reviewed in this series of papers.) The rest of the citations refer to methods of research.

1. Macbride: *Transactions of the Linnean Society of London*, London, 1818, **12**, 48–52.
2. Hooker: *Nature*, London and New York, 1874, **10**, 366–372.
3. Hooker: *Report of the Forty-third Meeting of the British Association for the Advancement of Science*, 1874, *Notes and Abstracts of Miscellaneous Communications to the Sections*, London, 1875, 102–116.
4. Mellichamp: *Proceedings of the American Association for the Advancement of Science*, Twenty-third Meeting, 1874, Salem, 1875, B, 113–133.
5. Edwards: *Proceedings of the California Academy of Sciences*, 1875, San Francisco, 1876, **6**, 161–166.
6. Canby: *Proceedings of the American Association for the Advancement of Science*, Twenty-third Meeting, 1874, Salem, 1875, B, 64–72.
7. Ames: *California Horticulturist and Floral Magazine*, San Francisco, 1880, **10**, 225–229.
8. Batalin: *Acta Horti Petropolitani*, St. Petersburg, 1880, **7**, 343–359.
9. Schimper: *Botanische Zeitung*, Leipzig, 1882, **40**, 225–233.
10. Higley: *Bulletin of the Chicago Academy of Sciences*, Lake Geneva, Wisconsin, 1885, **1**, 41–55.
11. Zipperer: *Inaugural-Dissertation*, Erlangen, 1886; *Botanisches Centralblatt*, Cassel, 1887, **29**, 358–359.
12. Goebel: Pflanzenbiologische Schilderungen, Elwert, Marburg, 1893, **2**, 166–170. The work on the genus *Sarracenia* but not that on *Darlingtonia* is summarized in *Naturwissenschaftliche Rundschau*, Braunschweig, 1893, **8**, 566–568.
13. Lambert: *Annales d'hygiène et de médecine coloniales*, Paris, 1902, **5**, 652–662.
14. Fenner: *Flora oder allgemeine botanische Zeitung*, Marburg, 1904, **93**, 335–434; especially pages 351–357.
15. Robinson: *Torreya*, New York, 1908, **8**, 181–194.
16. Mellichamp: *American Naturalist*, Boston, 1877, **11**, 432–433.
17. Watson: *American Naturalist*, Boston, 1877, **11**, 564.
18. Hepburn, St. John, and Jones: *Proceedings of the American Philosophical Society*, Philadelphia, 1918, **57**, 127–129.
19. Hepburn, St. John, and Jones: *Journal of the Franklin Institute*, Philadelphia, 1920, **189**, 147–184.
20. Hepburn and Jones: *Contributions from the Botanical Laboratory of the University of Pennsylvania*, Philadelphia, 1919, **4**, 460–463.
21. Burnett: *Quarterly Journal of Science, Literature, and Art*, London, 1829, July to December, 279–292.
22. Gray: Darwiniana. Appleton, New York, 1876, 330; copyright 1876.
23. Porcher: *Charleston Medical Journal and Review*, Charleston, 1849, **4**, 1–13.
24. Björklund and Dragendorff: *Pharmaceutische Zeitschrift für Russland*, St. Petersburg, 1863–1864, **2**, 317–325, 344–352, 369–378.
25. Björklund and Dragendorff: *Archiv der Pharmacie*, Hannover, 1864, **169** (2 Riehe, **119**), 93–124. Reprint of citation 24.
26. New York County Medical Society. Report of Committee on Sarracenia purpurea: *American Medical Times*, New York, 1864, **8**, 7–8, 18–19.
27. Martin: *Bulletin générale de Thérapeutique médicale et chirurgicale*, Paris, 1865, **63**, 308–311.

28. Martin: *Journal dem édecine, de chirurgie et de pharmacologie* publié par la Société des Sciences médicales et naturelles de Bruxelles, Bruxelles, 1865, **40**, 470–471. Reprint of citation 27.
29. Martin: *Annuaire de Thérapeutique de matière médicale de pharmacie et de toxicologie*, 1866, **26**, 72–73. Abstract of citation 27.
30. Schmitt: *Gazette Médicale de Strasbourg*, Strasbourg et Paris, 1871–1872, **31**, 78–79.
31. Vines: *Journal of Anatomy and Physiology*, Cambridge and London, 1876–1877, **11**, 124–127.
32. Hetét: *Comptes rendus des séances de l'Académie des Sciences*, Paris, 1879, **88**, 185.
33. Gies: *Journal of the New York Botanical Garden*, Lancaster, Pa., 1903, **4**, 37–39.
34. Meyer and Gies: *American Journal of Physiology*, Boston, 1905, **13**, xxxiii–iv.
35. Clark: *Dissertation*, Faculty of Pure Science, Columbia University, Easton, Pa., 1910, 79.
36. Palmer: *American Journal of Pharmacy*, Philadelphia, 1869, **41** (3 Series, **17**), 292, 396.
37. Roe: *Therapeutic Gazette*, Detroit, 1880, **4** (New Series, **1**), 224.
38. Rusby: *Therapeutic Gazette*, Detroit, 1884, **8** (New Series, **5**), 546–548.
39. Miles, H. C.: *Transactions of the Epidemiological Society of London*, London, 1863, **1**, 278–281; read November 4, 1861.
40. Miles, H. C.: *Lancet*, London, 1862, **2**, 430–431.
41. Morris: *American Medical Times*, New York, 1862, **4**, 297–298.
42. Morris: *Chicago Medical Examiner*, Chicago, 1862, **3**, 438–440.
43. Morris: *Journal of Materia Medica*, New Lebanon, N. Y., 1862, New Series, **4**, 346–347.
44. Morris: *American Journal of Pharmacy*, Philadelphia, 1862, **34** (3 Series, **10**), 362–364.
45. Miles, H. C.: *Lancet*, London, 1862, **2**, 665.
46. Miles, C.: *Lancet*, London, 1862, **2**, 241.
47. Morris: *Lancet*, London, 1862, **2**, 638.
48. Logie: *American Journal of Pharmacy*, Philadelphia, 1866, **38** (3 Series, **14**), 308–310.
49. Cigliano: *Il Dinamico*, 1871. Translation by Lilienthal in *American Observer*, Detroit, 1871, **8**, 467–470.
50. Editorial Note: *Medical and Surgical Reporter*, Philadelphia, 1862, **8**, 391.
51. Roe: *Therapeutic Gazette*, Detroit, 1880, **4** (New Series, **1**), 6–7.
52. The Homeopathic Pharmacopœia of the United States Published under the Direction of the Committee on Pharmacopœia of the American Institute of Homœopathy, 3d edition, Revised, Otis Clapp & Son, Agents, Boston, 1914, 510–511; copyright 1914.
53. The American Homœopathic Pharmacopœia, 8th edition, Boericke & Tafel, Philadelphia, 1906, 402–403; copyright 1904.
54. Bute: *Hahnemannian Monthly*, Philadelphia, 1867, **2**, 424.
55. Oehme: *Hahnemannian Monthly*, Philadelphia, 1876, **11**, 535.
56. Macfarlan: *Homœopathic Physician*, Philadelphia, 1892, **12**, 100, 527; 1893, **13**, 376, 382, 441, 535.
57. Allen: Encyclopedia of Pure Materia Medica, Boericke and Tafel, New York and Philadelphia, 1878, 514–526; copyright 1878.
58. Hering: Guiding Symptoms of Our Materia Medica, Estate of Constantine Hering, Philadelphia, **9**, 222–228; copyright 1890.
59. Crica: *Journal of Homœopathic Clinics*, Philadelphia, 1869, **3**, 78. Also cited as *American Journal of Homœopathic Materia Medica*.
60. Berridge: *North American Journal of Homœopathy*, New York and San Francisco, 1874, **22** (New Series, **4**), 194.
61. Mouremans: *Revue homœopathique belge*, Bruxelles, 1874, **1**, 61–69. Abstracts of this paper appeared in *Hahnemannian Monthly*, Philadelphia, 1874, **10**, 178, and in *Annual Record of Homœopathic Literature* (Raue), New York and Philadelphia, 1875, **6**, 287–288.
62. Hale: Homœopathic Materia Medica of the New Remedies, 2d edition, Lodge, Detroit, 1867, 937–961; copyright 1866.
63. Houat: *North American Journal of Homœopathy*, New York, 1869, **18**, 70–86.
64. Hepburn: *Contributions from the Botanical Laboratory of the University of Pennsylvania*, Philadelphia, 1919, **4**, 419–442.
65. Hepburn: *Journal of the Franklin Institute*, Philadelphia, 1922, **194**, 771–781.

66. Hepburn: *Contributions from the Botanical Laboratory of the University of Pennsylvania*, Philadelphia, 1919, **4**, 442–451.
67. Dakin: *Journal and Proceedings of the Royal Society of Western Australia*, 1917–1918, Perth, 1919, **4**, 37–53.
68. Hepburn and St. John: *Contributions from the Botanical Laboratory of the University of Pennsylvania*, Philadelphia, 1919, **4**, 451–457.
69. Browne: A Handbook of Sugar Analysis, 1st Edition, Corrected, Wiley, New York, copyright 1912, 197, 391.
70. Spencer, Meyer, Rehfuss, and Hawk: *American Journal of Physiology*, Baltimore, 1916, **39**, 459–479.
71. du Noüy: *Journal of General Physiology*, New York, 1919, **1**, 521–524.
72. Central Scientific Company, *Bulletin* 82, Chicago, 1921.
73. Wherry: *Journal of the Washington Academy of Sciences*, Baltimore, 1916, **6**, 672–679.
74. Wherry: *Journal of the Washington Academy of Sciences*, Baltimore, 1918, **8**, 589–598.
75. Wherry: *Journal of the Washington Academy of Sciences*, Easton, 1919, **9**, 305–309.
76. Wherry: *Journal of the Washington Academy of Sciences*, Easton, 1920, **10**, 217–223.
77. Wherry and Adams: *Journal of the Washington Academy of Sciences*, Easton, 1921, **11**, 197–202.
78. Wherry: *Ecology*, Lancaster, Pa., 1920, **1**, 160–173.
79. Wherry: *Annual Report of the Board of Regents of the Smithsonian Institution* for the year ending June 30, 1920, Washington, 1922, 247–268.
80. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Second Edition. Washington, 1925, 115, 180.
81. *Pharmacopœia of the United States of America*, **10**, Philadelphia, 1925, 352–354.
82. Rivas: *Journal of the American Medical Association*, Chicago, 1908, **50**, 1492–1495.
83. Rivas: *Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten, Erste Abteilung, Originale*, Jena, 1912, **63**, 547–550.
84. Crabill and Reed: *Biochemical Bulletin*, New York, 1915, **4**, 30–44.
85. Gotschlich: Kolle und Wassermann, Handbuch der pathogenen Mikroorganismen, 2. Auf., Jena, 1912, **1**, 102.
86. Clark: The Determination of Hydrogen-Ions, Williams and Wilkins Company, Baltimore, 1920, 67.
87. Clautriau: *Mémoires courronnés et autres mémoires publiés par l'Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique, Collection in 8°*, Bruxelles, 1899–1900, **59**, third memoir.
88. Van Slyke and Cullen: *Journal of the American Medical Association*, Chicago, 1914, **62**, 1558–1559.
89. Pfeffer: *Landwirtschaftliche Jahrbücher*, Berlin, 1877, **6**, 969–998.
90. Levy, Rowntree, and Marriott: *Archives of Internal Medicine*, Chicago, 1915, **16**, 389–405, especially 392.
91. Sörensen: *Biochemische Zeitschrift*, Berlin, 1909, **22**, 352–356.
92. Sörensen: *Ergebnisse der Physiologie*, Wiesbaden, 1912, **12**, 393–532, especially 437.
93. Giles: Sutton, Systematic Handbook of Volumetric Analysis, 10th edition, Philadelphia, Blakiston, 1911, 309, footnote.
94. Wherry: *Proceedings of the Academy of Natural Sciences of Philadelphia*, Philadelphia, 1920, **72**, 84–111, especially 87.
95. Macfarlane. Sarraceniaceæ, in Engler, Das Pflanzenreich, 34 Heft, **4**, 110. Leipzig, Engelmann, 1908.